Project ID # VAN028

Electric Vehicle – Grid Benefits Analysis

PI: Colin Sheppard

Presenter: Alan Jenn

Team: Gordon Bauer, Jeff Greenblatt, Brian Gerke, Anand Gopal

Lawrence Berkeley National Laboratory

2019 DOE VTO Annual Merit Review

June 13, 2018

Overview

Timeline

- Start date: October 2017
- End date: September 2019
- Percent complete: 90%

Barriers

- Indicators and methodology for evaluating environmental sustainability and cost impacts
- Relating component-level technologies to national-level benefits

Budget

- Total project funding: $770K
  - DOE share: 100%
- FY 2017: $170K
- FY 2018: $350K
- FY 2019: $250K

Partners

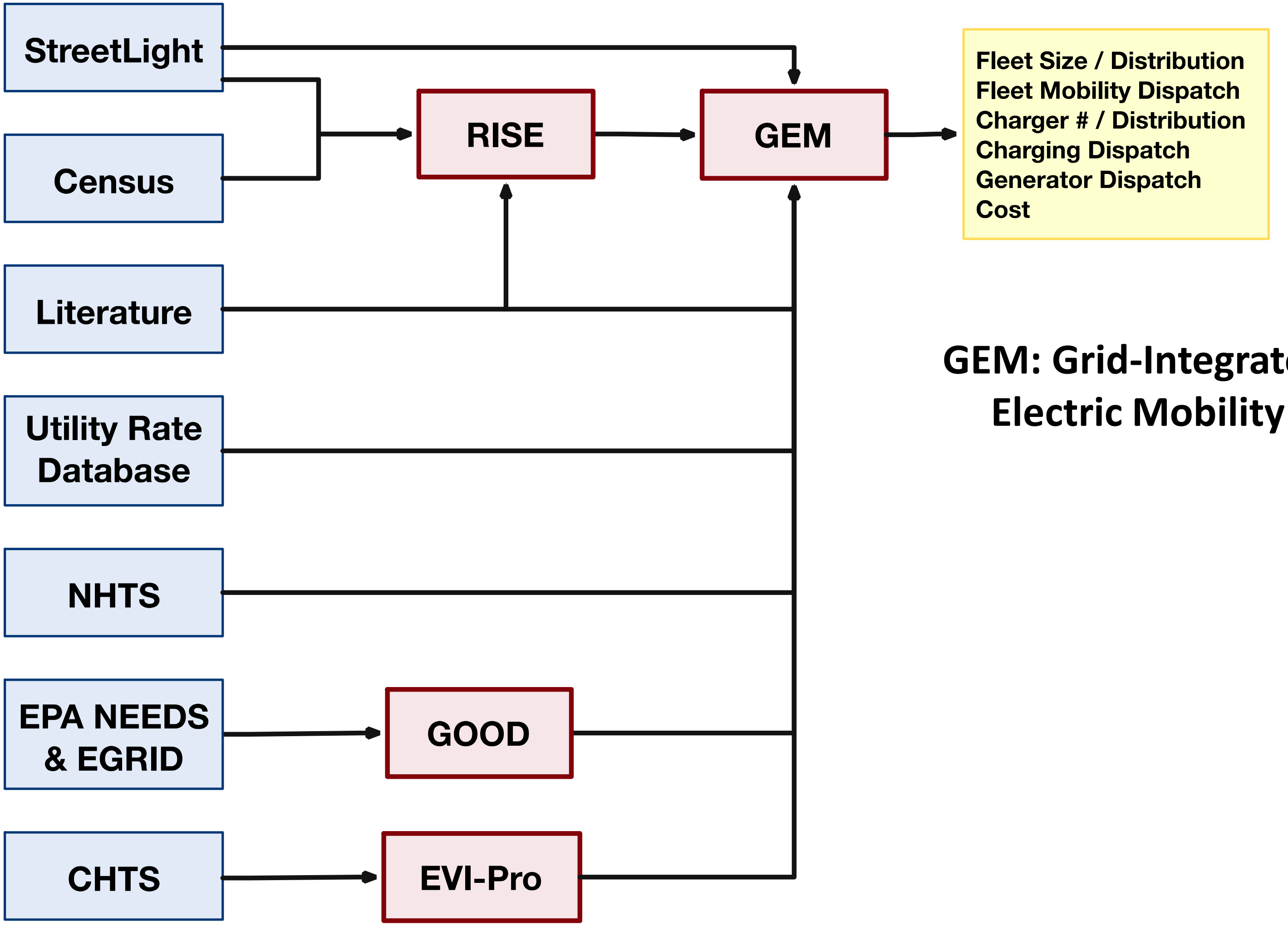
- Project Lead: LBNL
- Partners: UC Davis, Emerging Futures LLC

Objectives

Relevance

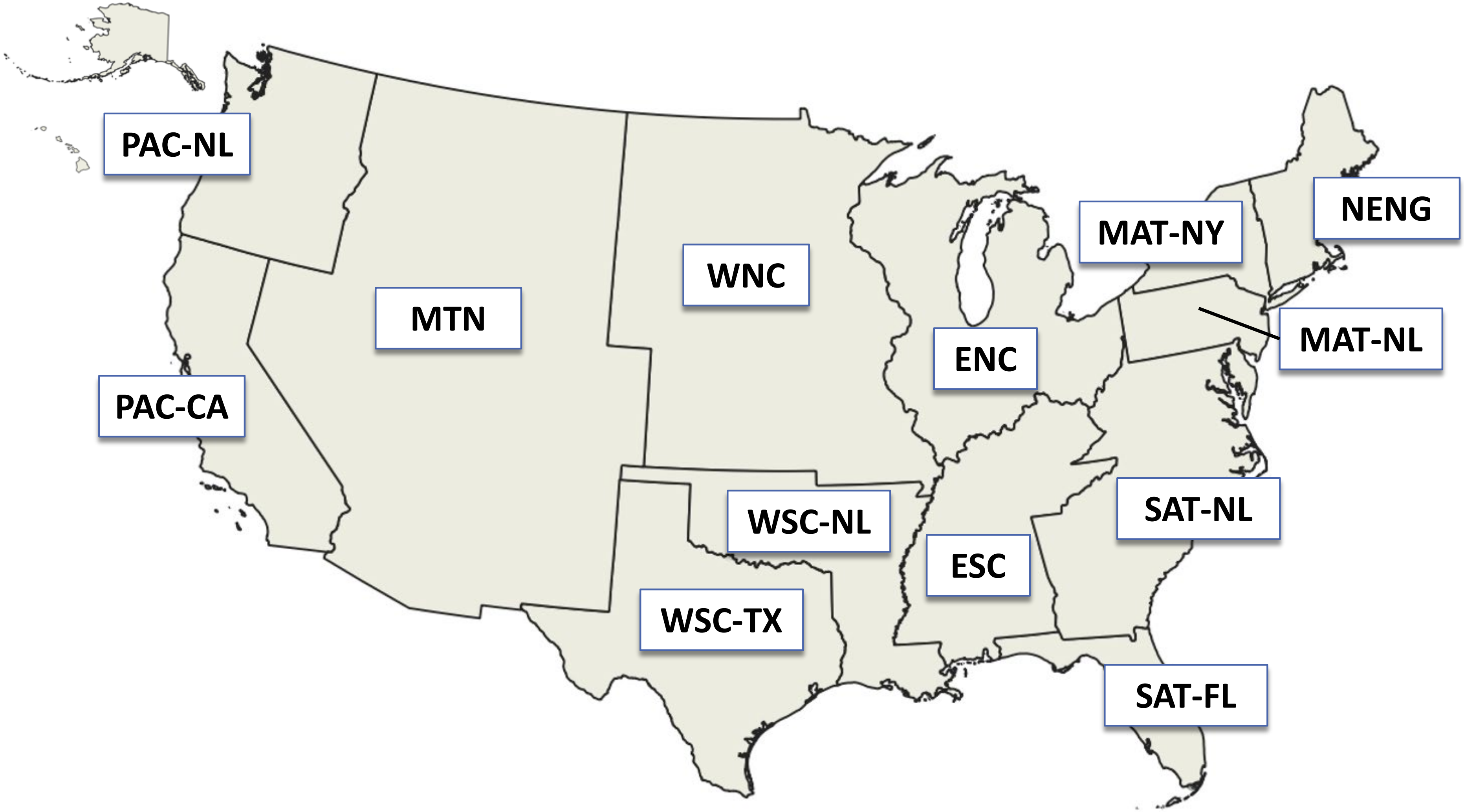
- Estimate the costs and benefits on the transportation and power systems of integrating millions of plug-in electric vehicles
  - Impact on power system generators including the curtailment of intermittent renewable energy
  - Impact on grid operating cost
  - Impact on fleet and charging infrastructure requirements
- By accounting for charging profile and load flexibility within personally owned EV fleet as well as future fleets of shared automated EVs (SAEVs) serving mobility on-demand
- The grid is simulated as dispatched, allowing the system costs to be minimized across both transportation and power sectors

GEM Model Co-Optimizes Mobility and Grid



GEM: Grid-Integrated Electric Mobility

Geographic Extent



Optimization Model

Approach

- How will firms allocate shared automated EVs to serve mobility demand?
  - Larger battery capacities or smaller?
  - Faster chargers or slower?
- How will charging be scheduled in response to time-varying cost of electricity?
  - More vehicles => more flexibility but at a higher fleet cost
- How will electricity generators be dispatched in light of the flexible load?

Problem Formulation

- Objective:
  - Minimize operational cost of serving demand + generating electricity + amortized fleet and infrastructure costs
- Decision Variables:
  - # of Vehicles in Fleet (by range, e.g. 75 mile vs 150 mile)
  - # of Chargers to Install (by power capacity)
  - Which vehicles serve which trips
  - Which vehicles charge, when, and at what power level
  - Which electricity generators are dispatched
  - How much electricity is imported/exported across regions

(Non-linear Convex Program)

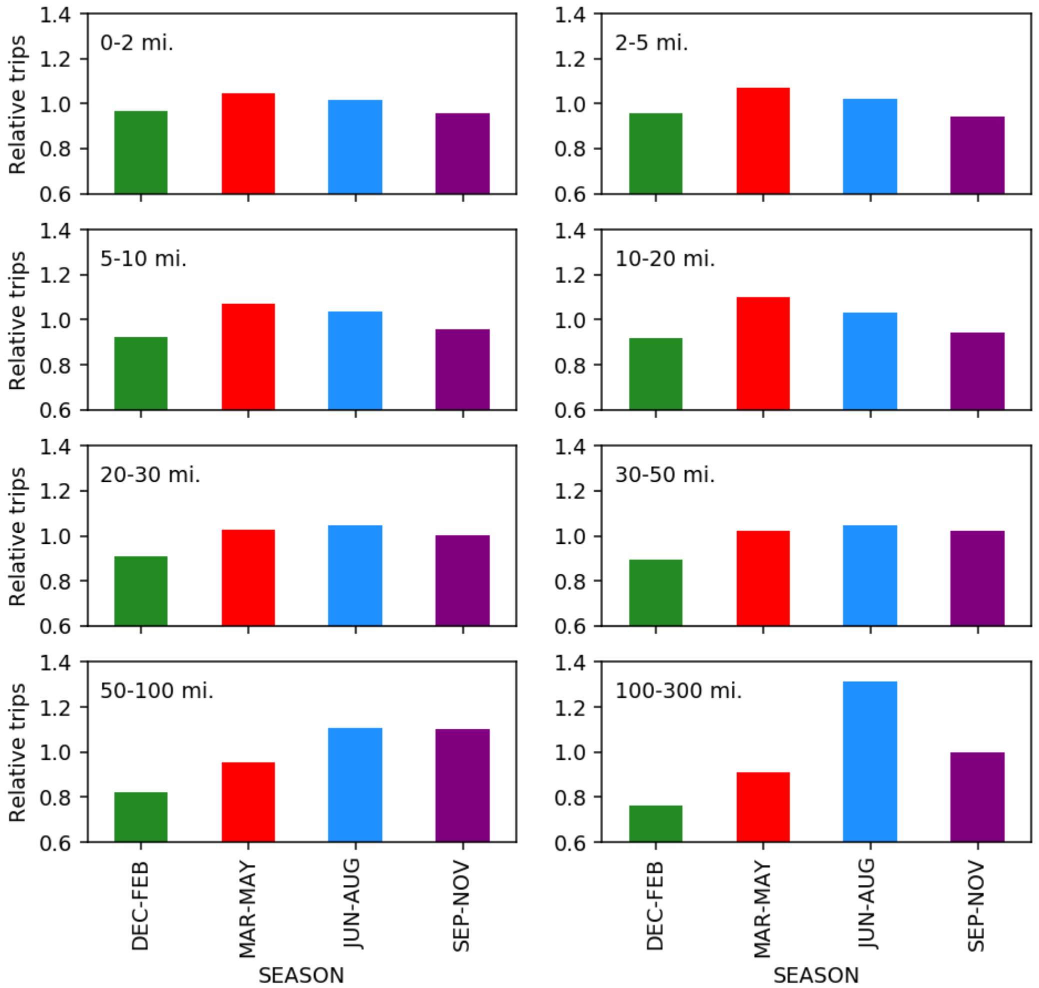
Problem Formulation

- Constrained to:
  - All mobility demand is served
    - Vehicles allocated to demand within a time period based on
      - average sharing factor (passengers per vehicle)
      - distribution of speed
      - distribution of trip distances
      - ratio of total VMT / with-passenger VMT
  - Number of vehicles charging < number of charging plugs
  - Energy conservation
  - Batteries begin/end at full
  - Generation constraints on ramping and transmission

Estimating trip demand from NHTS

Progress

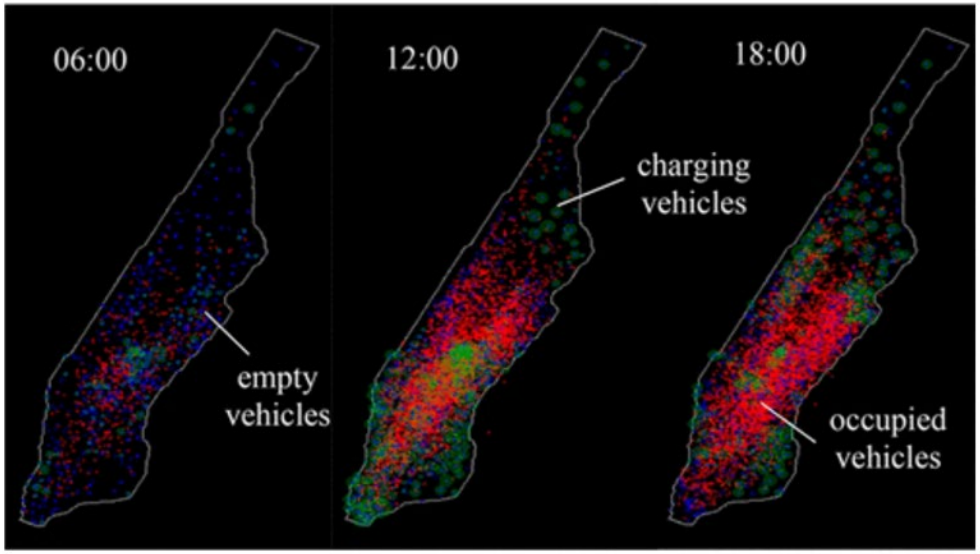
- Using the 2017 NHTS data, we estimate demand for trips, disaggregated by
  - Trip distance
  - Hour of day
  - Region (9 census regions + 4 largest states)
  - Urban vs. rural area
  - Type of day (weekend, midweek, M/F)
  - Season



RISE Model: Adding Realism with Correction Factors

Progress

- GEM takes deadheading (traveling without a passenger) between trips as an exogenous input
- Deadheading to charge results in lower effective charging speed
- Spatial mismatch leads to some vehicles sitting idle at peak time

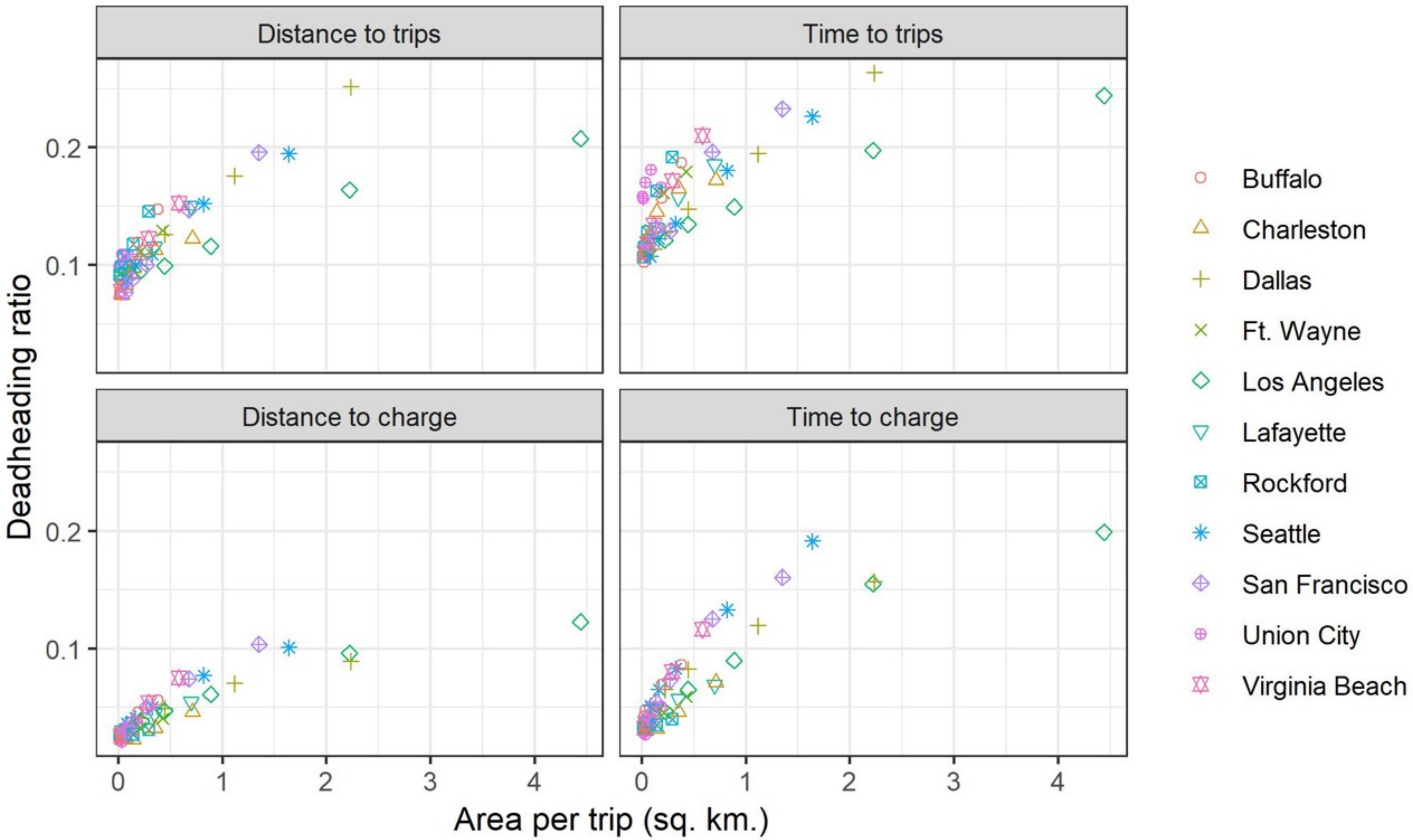


- Correction factors determined separately with a spatially-explicit agent-based simulation called RISE (**R**outing and **I**nfrastructure **S**imulation for **S**hared **E**lectric Vehicles)

Simulating cities with cellular GPS data

Progress

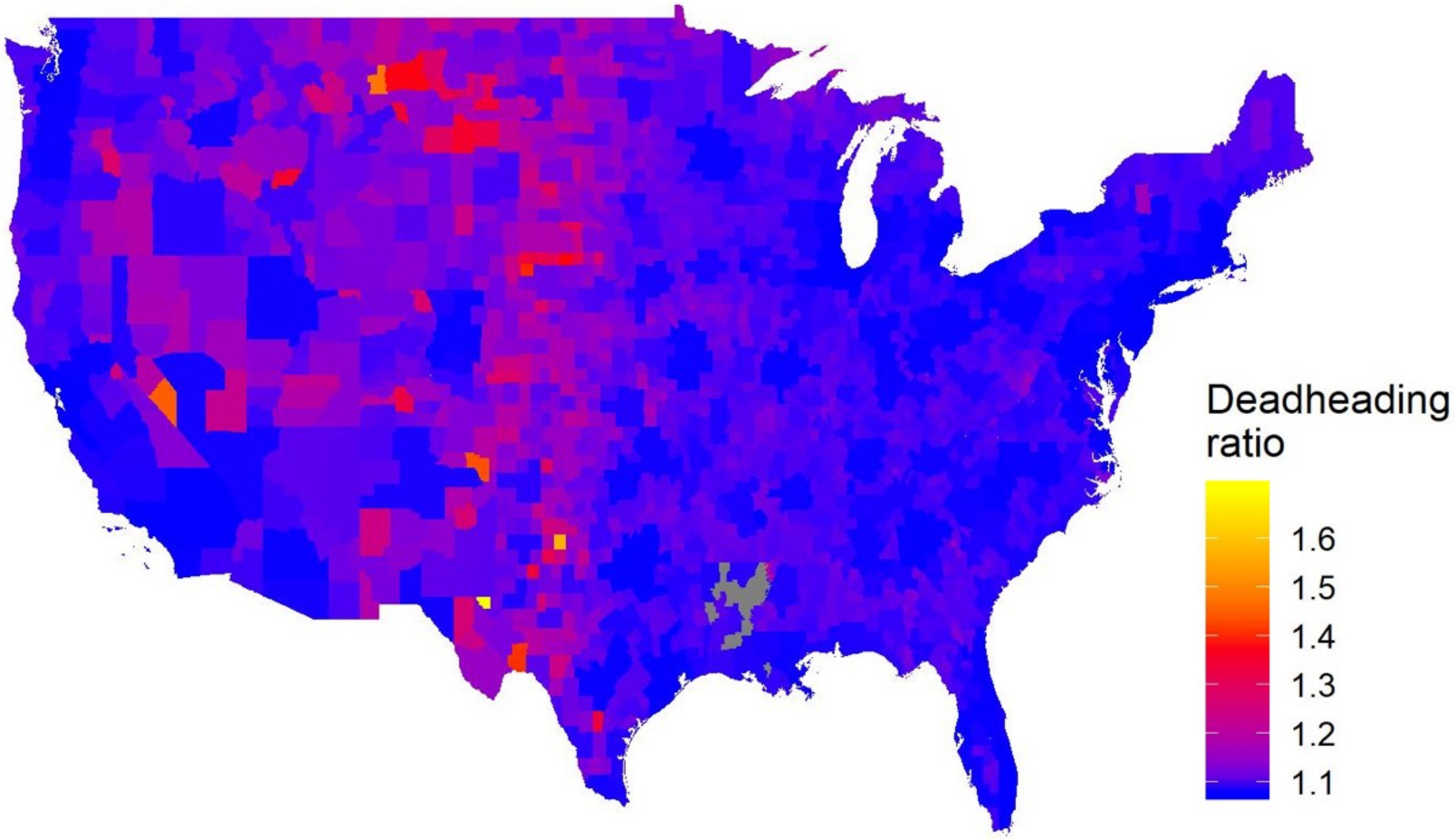
Deadheading correlated with trip density, systematic differences between cities are small



Extrapolation to national scale

Progress

If Shared, Autonomous, Electric Vehicles (SAEVs) serve all driving trips, high trip density leads to low deadheading in most areas



Aggregate Private EV model

Progress

Analogous Approach to CA Analysis

Simulated Mobility / Charging

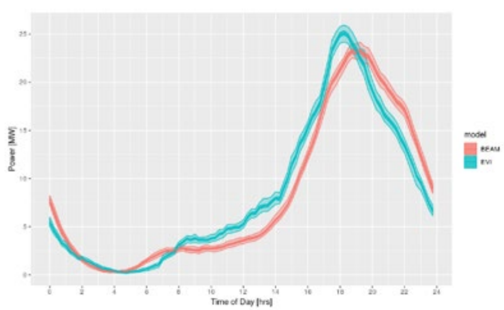
- EVI-Pro finds lowest cost charging schedule subject to assumptions on chargers levels & driver preference

Charging Sessions

- When and where for each charging session (fast, home or workplace etc.)

Aggregate Constraints

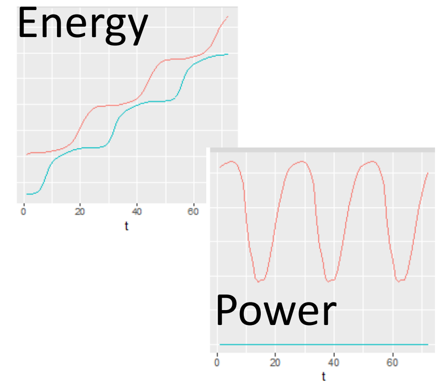
- Develop aggregate model in each region
- Coordinate EV charging power profiles subject to charging constraints



EVI-Pro + Post-Processing & Sampling Tool by HSU

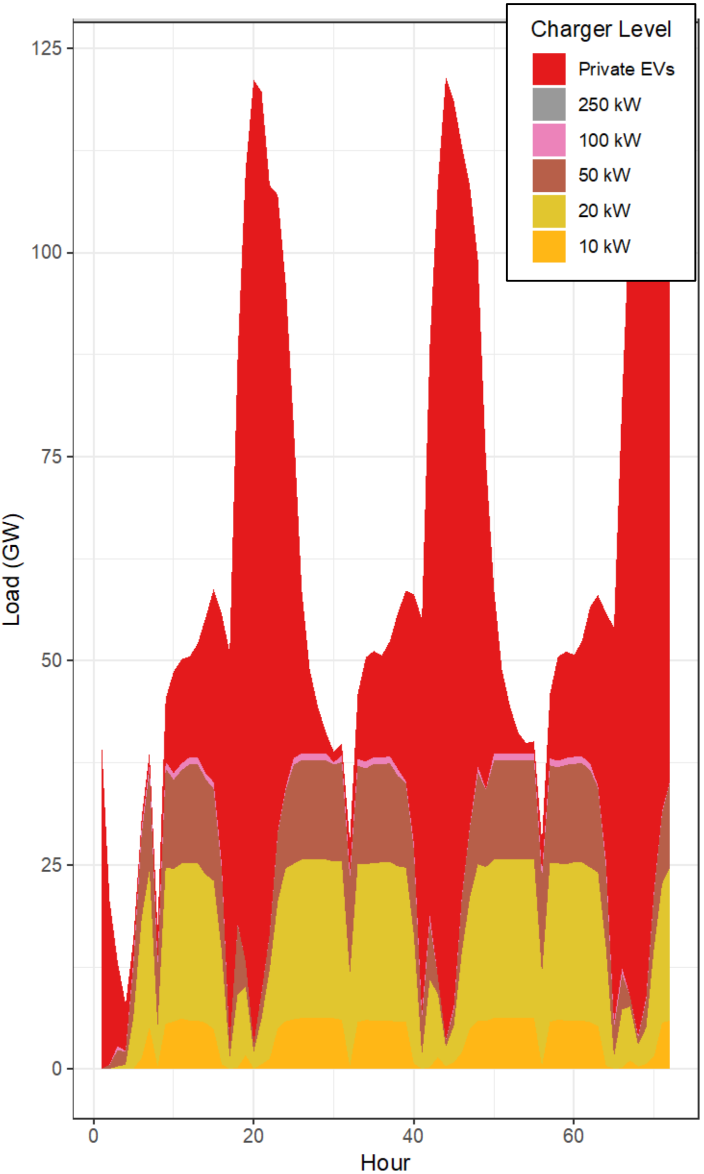
No.	Arrive time	Leave time	Arrive soc	Leave soc	power
1	18:00	22:00	0.4	0.9	6.6
2	15:00	17:00	0.6	0.8	3.3
3	11:00	14:00	0.7	0.6	6.6
…	…	…	…	…	…
N	19:00	07:00	0.3	1	6.6

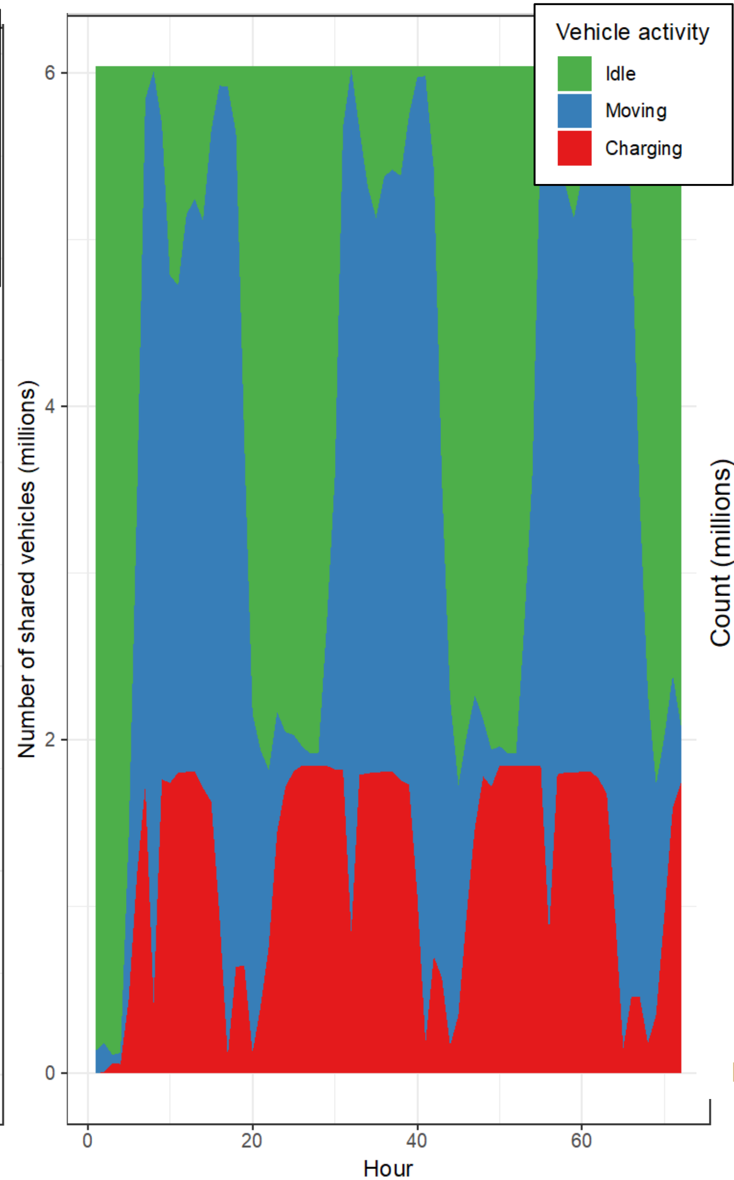
Individual EV Charging demands

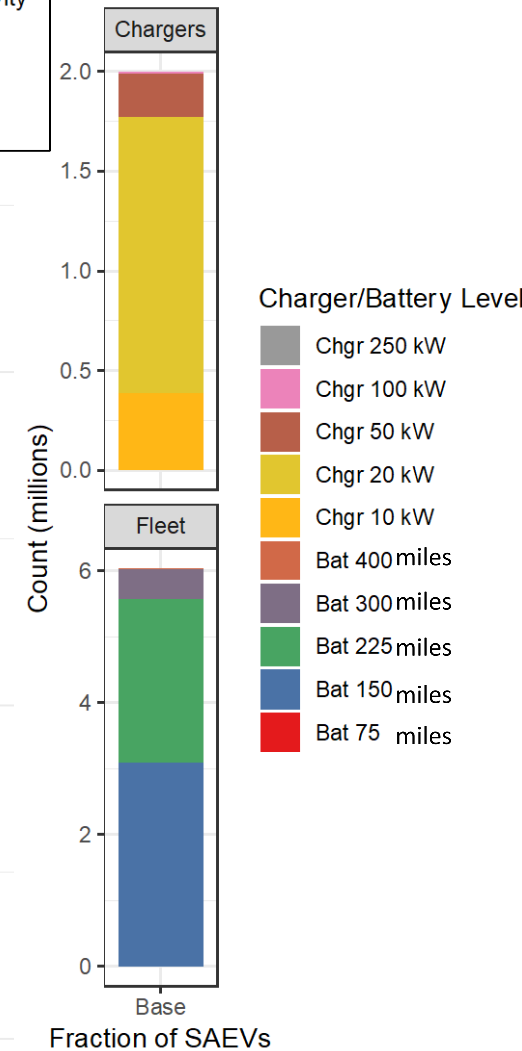


Aggregate EV charging demand model

Base Charging, Fleet, and Chargers

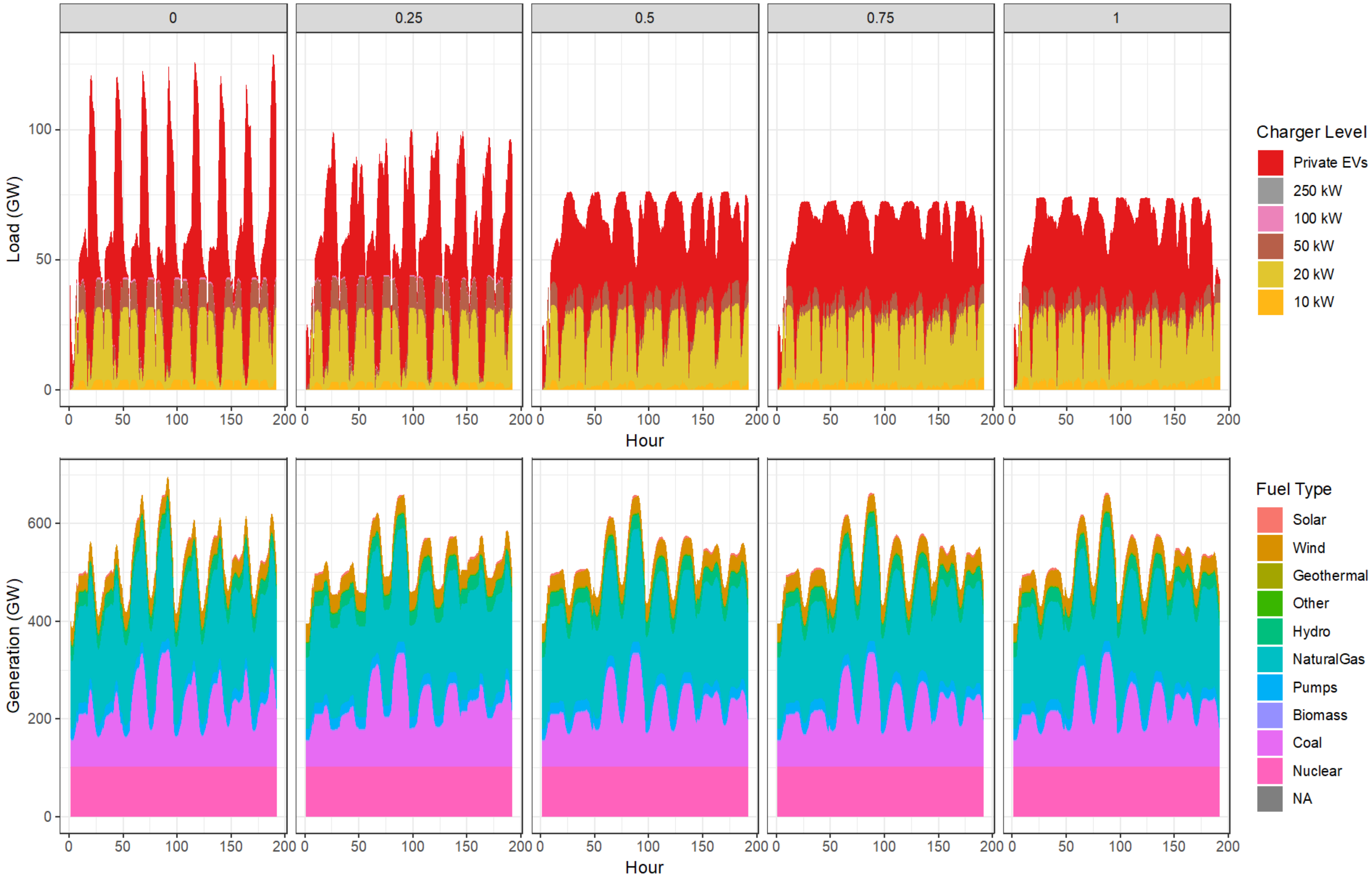






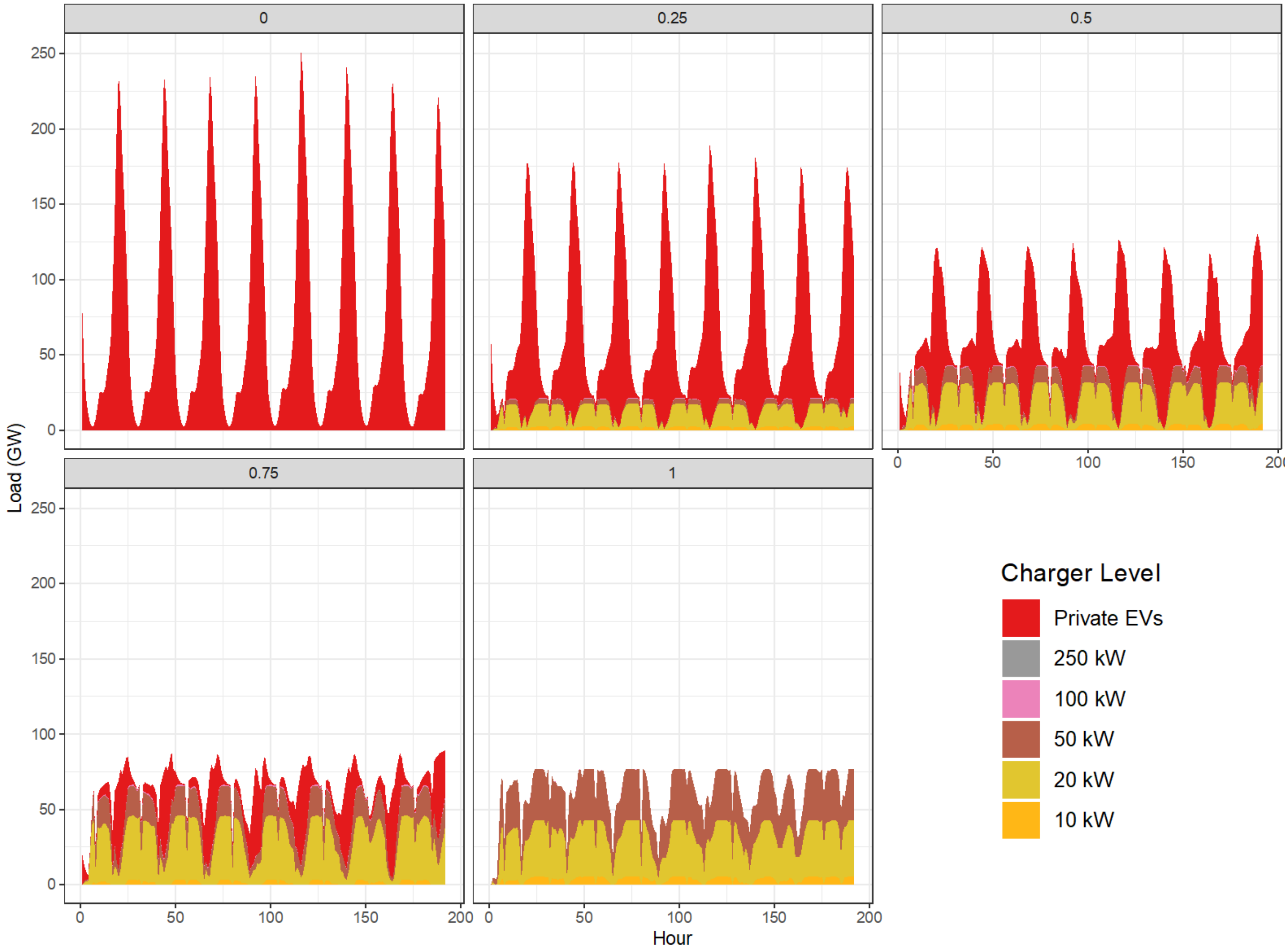
Smart Charging Smooths National Load

Accomplishment



Base Charging, Fleet, and Chargers

Accomplishment



Other Notable Results

Accomplishment

- If 100% of mobility currently served by light duty vehicles were instead served by SAEVs:
  - a fleet of 12M vehicles could service the demand
  - requiring 3M chargers of varying power capacities
  - increasing electricity demand by 1500 GWh/day or 11% of 2017 U.S. demand
  - increasing peak power demand by 77 GW or 11% of 2017 U.S. peak demand

Response to FY18 Reviewer Comments

- *The reviewer noted that this proposed future work will address key shifts—such as ride hailing—that will impact future vehicle use and charging requirements. The reviewer stated exploring the potential impact of future mobility trends on PEV charging will be of significant interest in understanding the impact on the grid and the costs/benefits from both a system and consumer perspective.*

  We agree that this topic is very relevant to the future of vehicle grid interaction and is why we devoted much of the last year to building the new capability now present in the GEM model

- *The reviewer said the project is well-coordinated with government and university partners in California. The reviewer explained that input from national stakeholders and increased interaction with the other VTO analysis performers should enable the project to have even more impact as well as benefit other projects within the portfolio.*

  We agree with the reviewer and we have sought out increased collaboration with other VTO performers (NREL) and we are interested in future opportunities to extend our impact.

Milestones on Schedule

Date	Milestone	Status
September 2018	Submitted journal article on benefits of shared / automated EVs at the national level	Complete
December 2018	Finalize infrastructure, vehicle fleet and grid-mix scenarios. Completion of coupling mobility model with national grid model. Briefing to program managers on progress.	Complete
March 2019	Completed analysis for all scenarios. Briefing on progress.	Complete
June 2019	Final results of analysis on shared scenarios using coupled model presented to HQ in a briefing.	On Schedule
September 2019	Final results of analysis on integrated scenarios (both shared and privately owned EVs) using coupled model presented to HQ in a briefing. Completed marginal grid mix results by region under different grid development scenarios for use in GREET tool.	On Schedule

Partners and contributors

- UC Davis
  - A project partner
- Emerging Futures LLC
  - A project partner
- Argonne National Laboratory - GREET
  - We have delivered emissions outputs from GEM to the GREET team for use in their FY18 efforts
- NREL
  - Source for modeled private EV charging data
- Humboldt State University Schatz Energy Research Center
  - Contributed to data processing of private EV charging data

Remaining Challenges and Barriers

- The optimization problem becomes very large as we add more and more simulation days, degrading performance
  - Solution: seek performance enhancements by pruning decision variables and constraints in the model implementation

- Simulation time horizon is still smaller than we would prefer (due to the above performance bottleneck)
  - Solution: either solve the bottleneck issue or devise a method to compose a solution with a larger time horizon from the results of solutions with smaller horizons

Upcoming tasks

- FY19
  - We intend to improve GEM computational efficiency to enable larger scale simulations to run in feasible time
  - We will adapt GEM to run in High Performance Computing environments
- Beyond FY19
  - We will add more sources of transportation electrification (e.g. trucking, transit, micromobility)

Any proposed future work is subject to change based on funding levels

Summary

- Approach – outlined technical details of optimization and associated constraints of the system
- Technical Accomplishments/Progress – finalized integration of mobility and grid modeling, comprehensive results for publication
- Collaboration – partners with universities and other national labs
- Future Research – adding TNC, micro-mobility, heavy-duty
- Relevance – extending VTO Benefits Analysis to include the upstream costs and benefits of EVs to the grid
- Resources – given our current resources we have been successful at accomplishing our goals to date

TECHNICAL BACKUP SLIDES

GEM Model Co-Optimizes Mobility and Grid